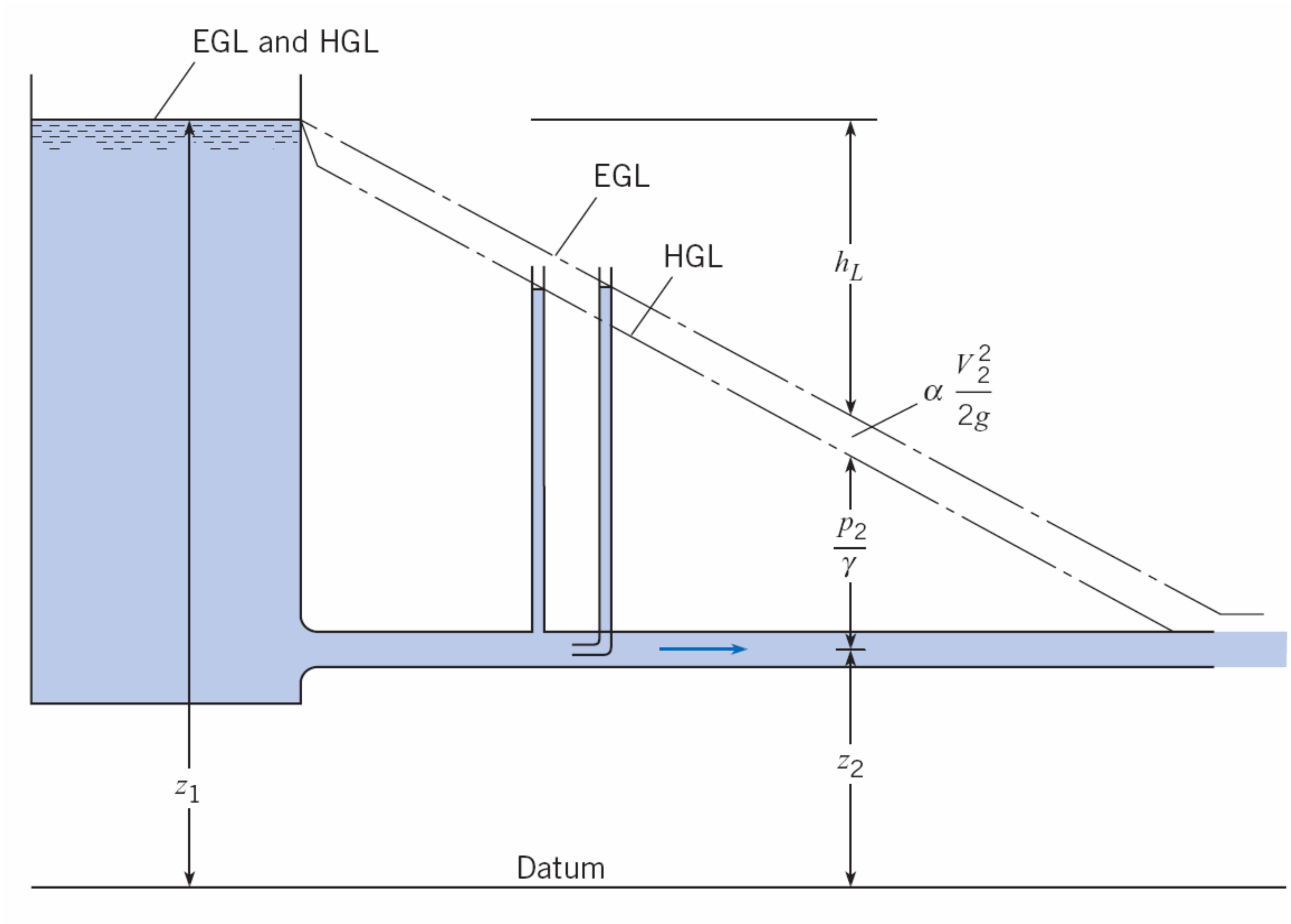
ENERGY PRINCIPLE

Concept of the Hydraulic and Energy Grade Lines

$$\left(h_P + \frac{p_1}{\rho g} + z_1 + \alpha_1 \frac{\overline{V}_1^{\,2}}{2g}\right)_{Mech.part} = \left(h_T + \frac{p_2}{\rho g} + z_2 + \alpha_2 \frac{\overline{V}_2^{\,2}}{2g}\right)_{Mech.part} + h_{Loss}$$

1. **In general the left hand side of the equation above represent the pump $[h_p]$, fluid head (piezometric head) $\left[\frac{p_1}{\gamma} + z_1\right]$,and the flow work $\left[\alpha_1 \frac{V_1^2}{2g}\right]$ at flow upstream.**

2. **In general the right hand side of the equation above represent the turbine (h_T), fluid head (piezometric head) $\left[\frac{p_2}{\gamma} + z_2\right]$, the flow work $\left[\alpha_2 \frac{V_2^2}{2g}\right]$ and head loss $[h_{Loss}]$ at flow downstream.**



By analyzing the Figure Above, the followings can be deduced:

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1. The height of the $\left[\frac{p}{\gamma}\right]$ line is called the **(Hydraulic Grade Line (HGL)**

2. The height of the $\left[\frac{p}{\gamma}+\alpha\frac{V^2}{2g}\right]$ line is called the **(Energy Grade Line (HGL**

3. EGL is above HGL by a distance $\left[\alpha\frac{V^2}{2g}\right]$

4. For a lake or a reservoir, EGL and HGL will Coincide because the velocity is zero.

5. Head loss for a flow in a pipe as shown in the Figure always means that the EGL will slope downwards in the direction of flow.

6. For a steady flow in a pipe where the diameter, roughness and shape is the same, the slope $\left[\frac{\Delta h}{\Delta L}\right]$ is constant.

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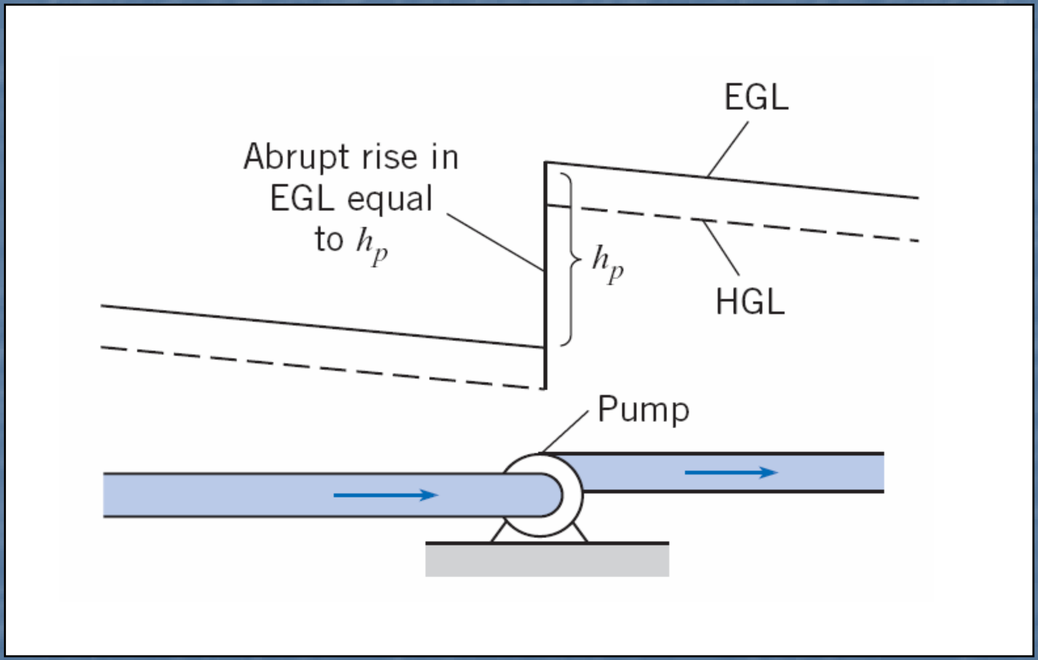
Also, the lines of HGL and EGL are drawn for the followings cases:

1. An exception to **point (5)** when a pump supplies energy to flow as shown in **Fig. below.**



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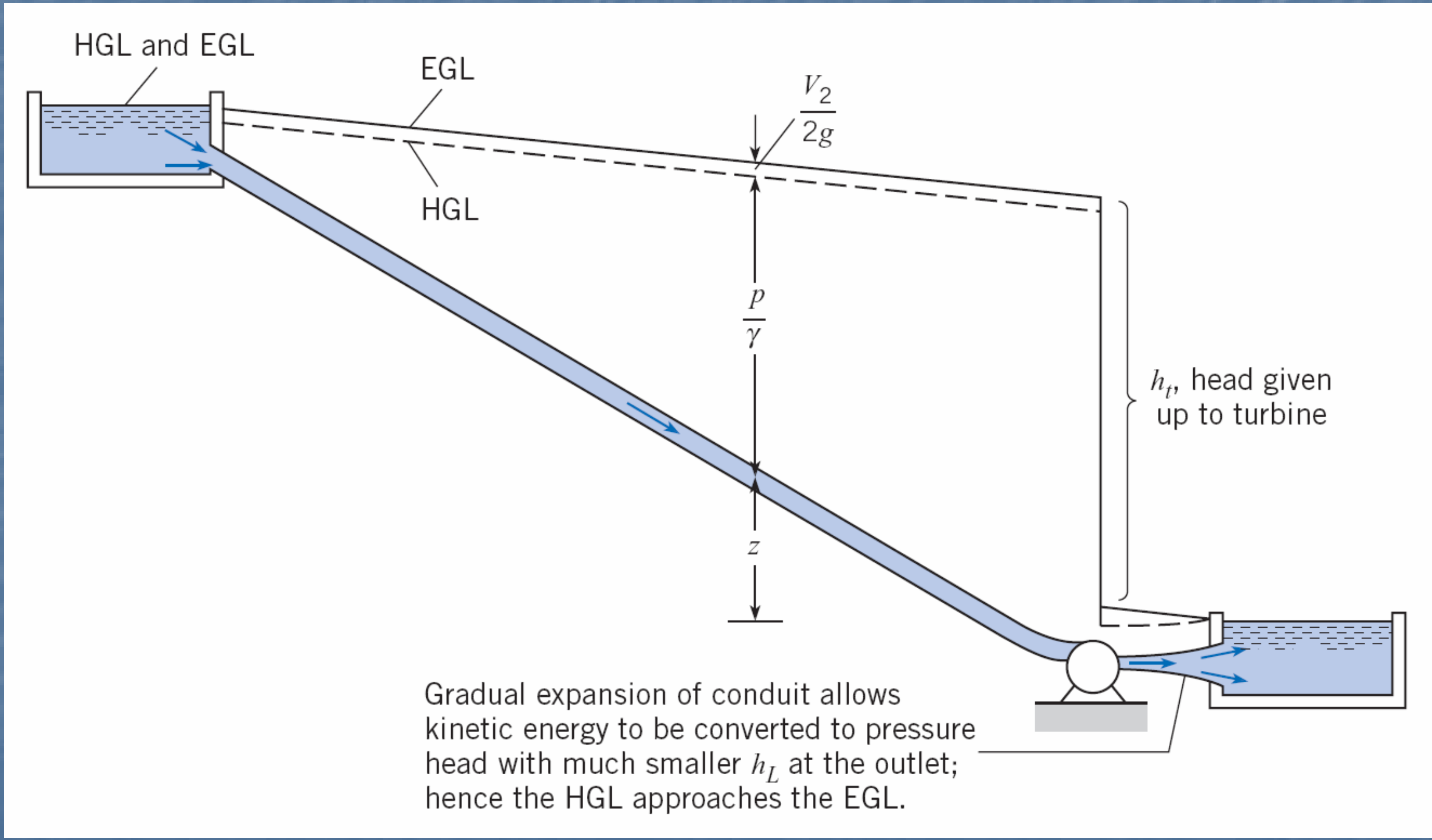
2. An exception to **point (5)** when a turbine extracts energy from the flow as shown in **Fig. below.**



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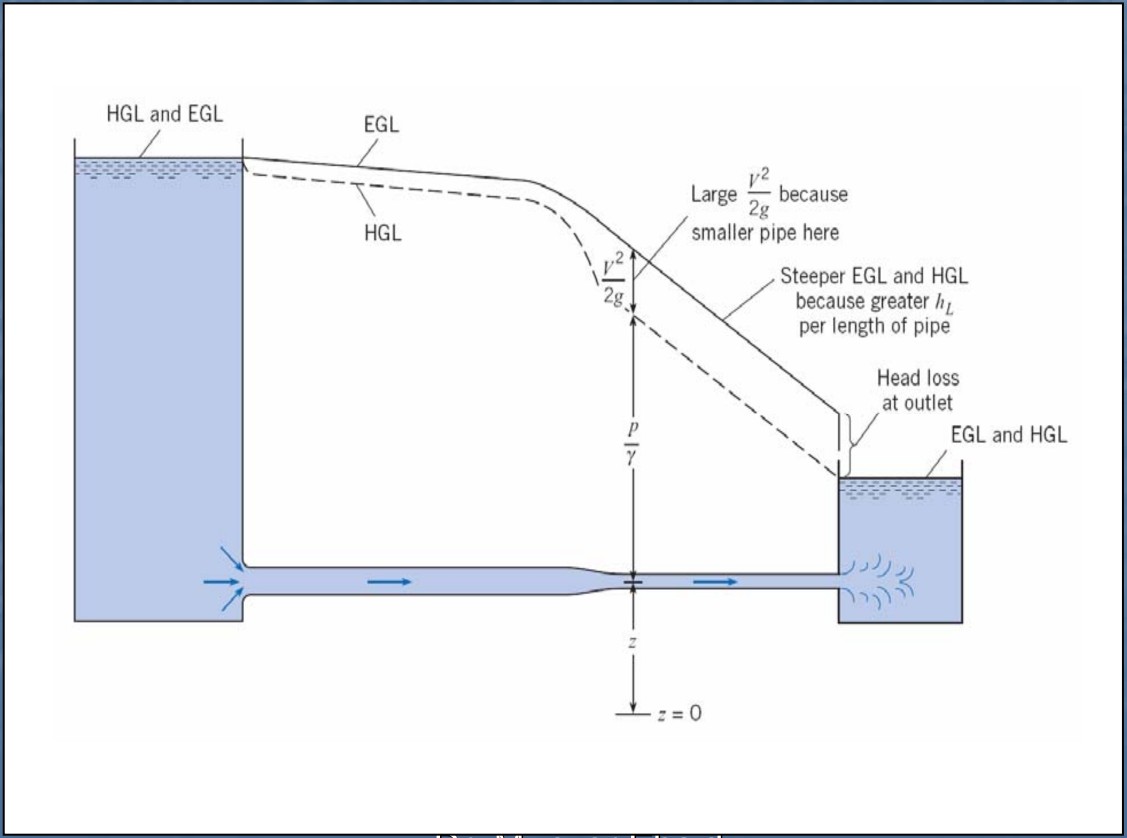
3. If the outlet to the reservoir is an abrupt expansion as shown

in Fig. below, all the kinetic energy is lost. Thus the EGL

drops an amount $\left[\alpha \frac{V^2}{2g}\right]$ at the outlet.



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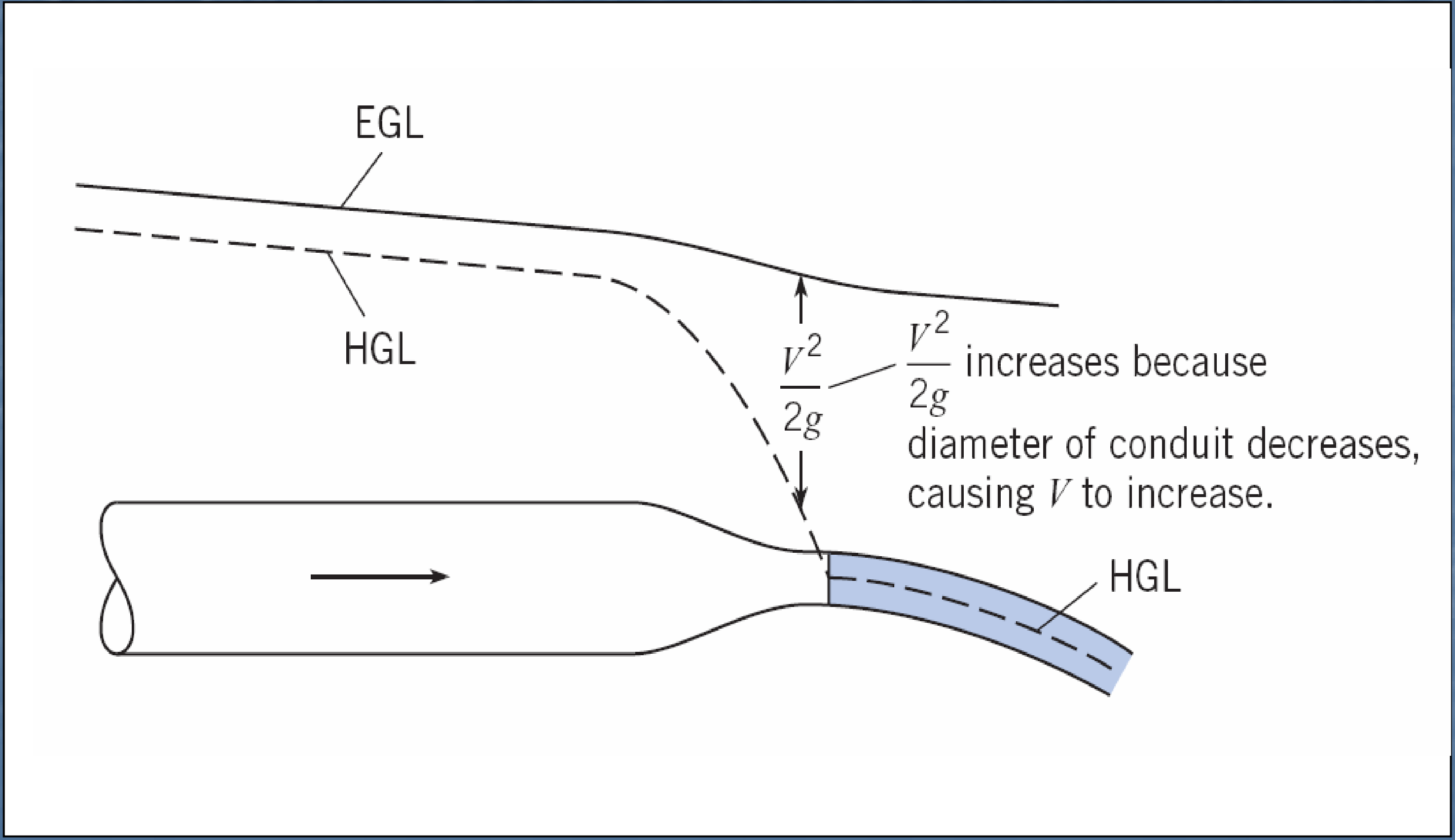
4. **If the flow passage changes diameter such as in a nozzle, the velocity changes and hence** the distance between the EGL and HGL $\left[\alpha \frac{V^2}{2g}\right]$ **will change as shown in Fig. below, at the outlet.**



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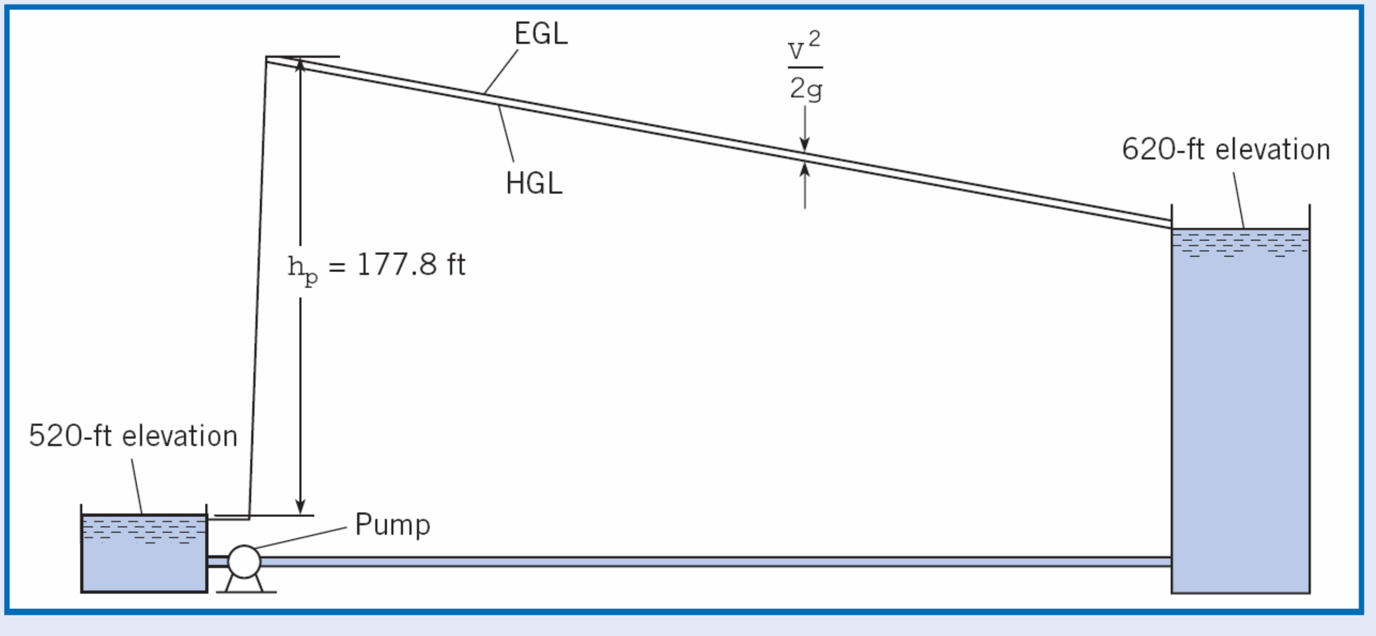
Example (7.7)



Given:

$$L_{pipe} = 5000\,ft,\ D_{pipe} = 1ft,\ \dot{Q} = 7.85\,ft^3/s,\ h_{Loss} = \left[0.01\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)\right]$$

Find:

$h_p, \dot{W}_p$ *and draw the HGL and EGL?*

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Solution

Applying the energy equation between point 1 & 2

$$\left(h_P+\frac{p_1}{\rho g}+z_1+\alpha_1\frac{\overline{V}_1^{\,2}}{2g}\right)_{Mech.part}=\left(h_T+\frac{p_2}{\rho g}+z_2+\alpha_2\frac{\overline{V}_2^{\,2}}{2g}\right)_{Mech.part}+h_{Loss}$$

$$Since \quad V_1=V_2=0, \quad p_1=p_2=0, \quad h_T=0, \quad \alpha_1=\alpha_2=1$$

i.e. Eqn above reduces to

$$(h_p+z_1)_{Mech.part}=(z_2)_{Mech.part}+h_{Loss}$$

$$z_1=520\,ft,\ z_2=620\,ft$$

$$V_{pipe}=\frac{\dot{Q}}{A}=10\,ft/s$$

$$h_{Loss}=0.01\times\frac{5000\times10^2}{1\times2\times9.81}=0.01ft$$

$$h_p=620-520+0.01=178\,ft$$

$$(\dot{W}_p)_{hp}=\gamma\dot{Q}h_p/550=158\,hp$$

END OF LECTURE (6)